2023 VIRTUAL INTERNATIONAL WORKSHOP ON LASER RANGING

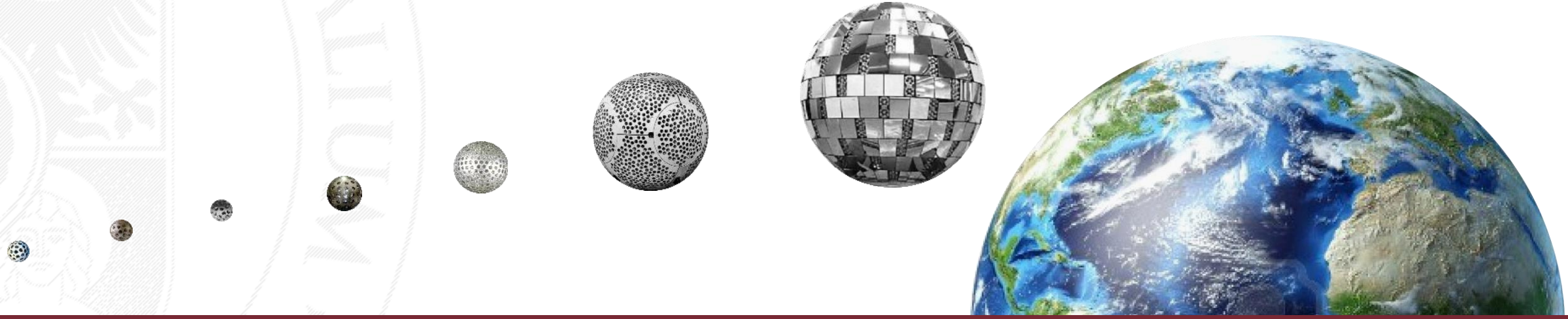
OCTOBER 16-20, 2023

NEW DEVELOPMENTS IN SATELLITE LASER RANGING

ILRS

WROCŁAW UNIVERSITY OF ENVIRONMENTAL AND LIFE SCIENCES

THE INFLUENCE OF GEODETIC SATELLITE ORBITAL PARAMETERS ON THE QUALITY OF GLOBAL GEODETIC PARAMETERES



Joanna Najder, Krzysztof Sośnica, Radosław Zajdel

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SIMULATIONS

We study the impact of adding satellite observations with different orbital parameters, in particular:

- **Semi-major axis – *a***

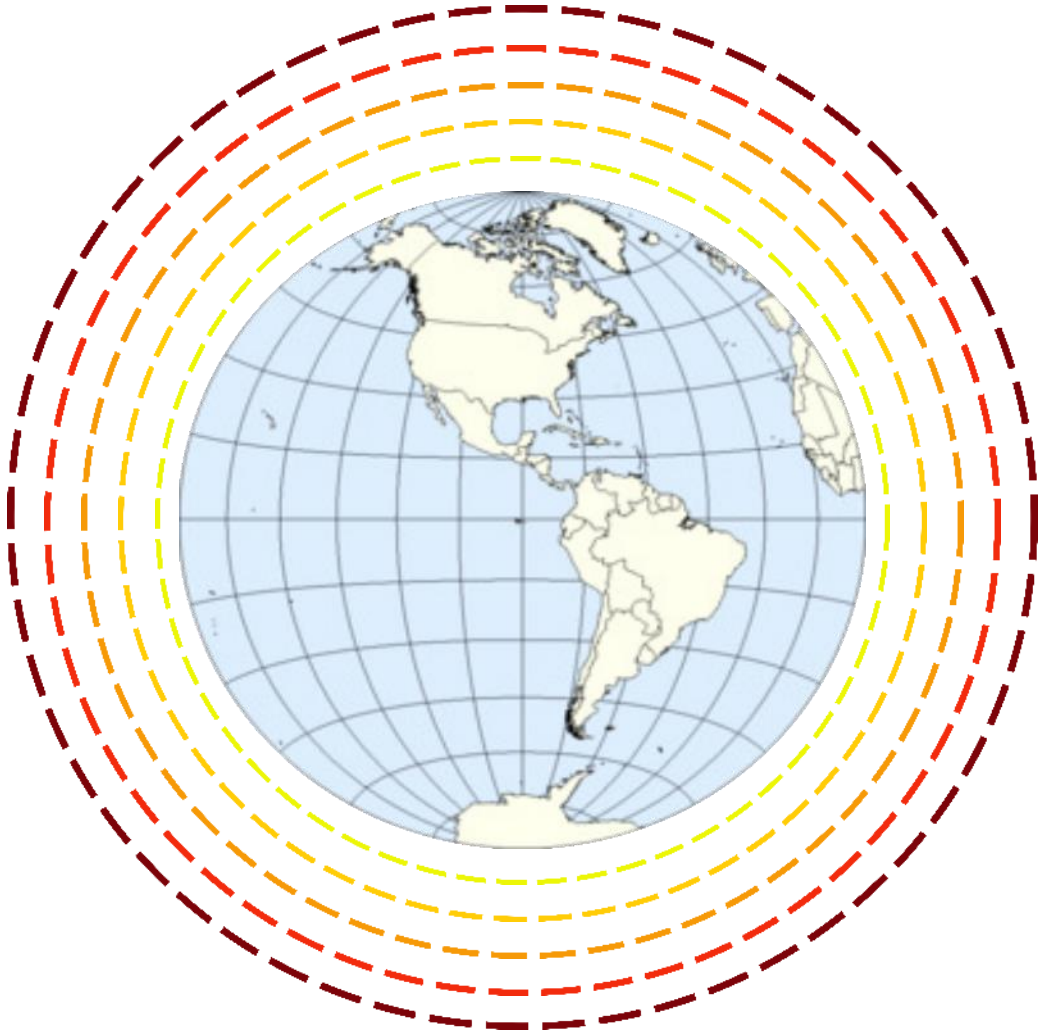
  LOW – 7 800 km (similar to LARES-1)

  MEDIUM – 10 000 km

  HIGH – 12 200 km (similar to LAGEOS-1/-2)

  HIGHER – 14 400 km

  HIGHEST – 16 600 km



SIMULATIONS

We study the impact of adding satellite observations with different orbital parameters, in particular:

- **Semi-major axis – *a***
- **Inclination angle – *i***

  range: 0-180° (interval 1°)

SIMULATIONS

We study the impact of adding satellite observations with different orbital parameters, in particular:

- **Semi-major axis – *a***
- **Inclination angle – *i***
- **Eccentricity – *e***

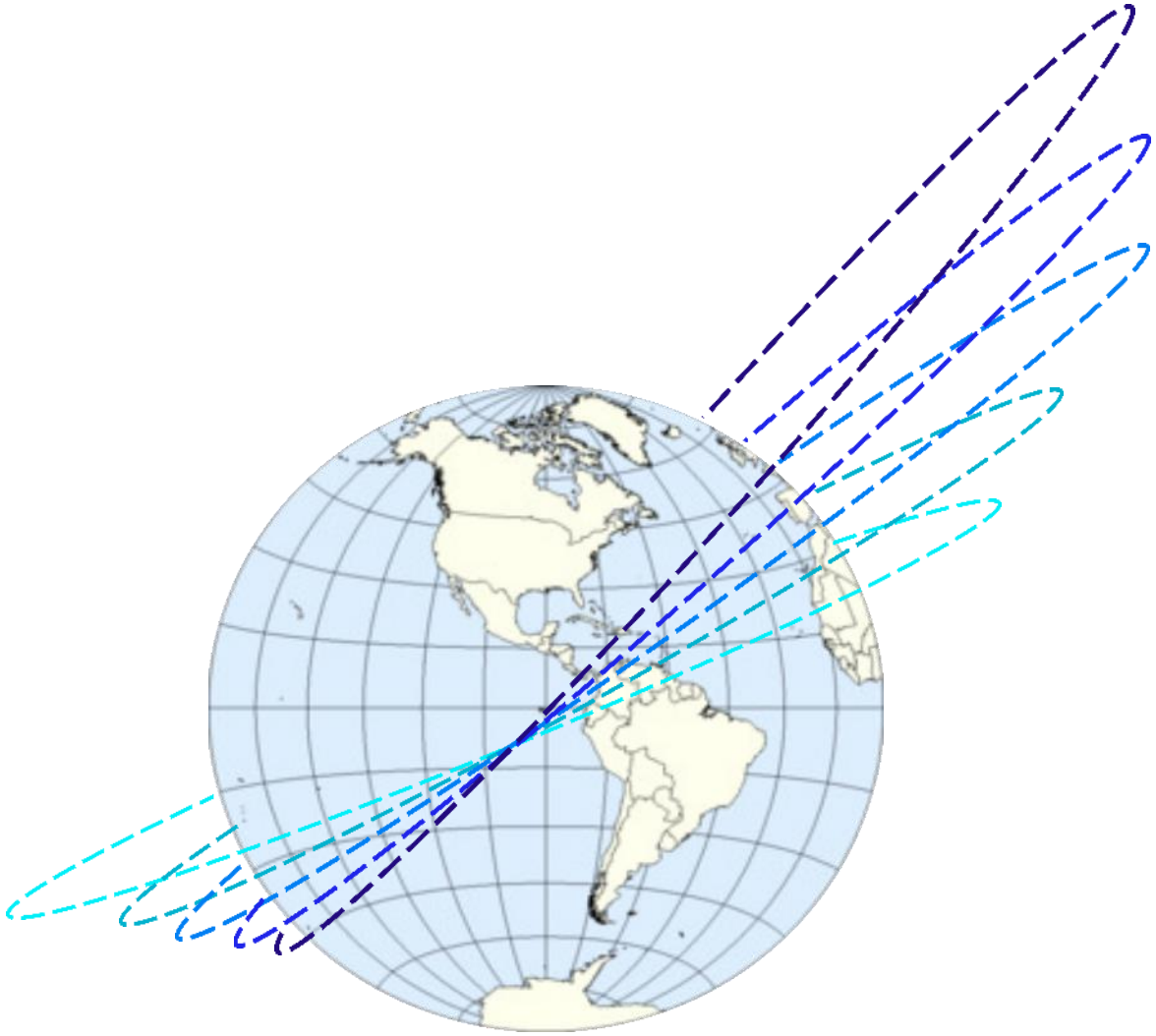
  LOW – 0,00 – 0,07

  MEDIUM – 0,00 – 0,28

  HIGH – 0,00 – 0,41

  HIGHER – 0,00 – 0,50

  HIGHEST – 0,00 – 0,565



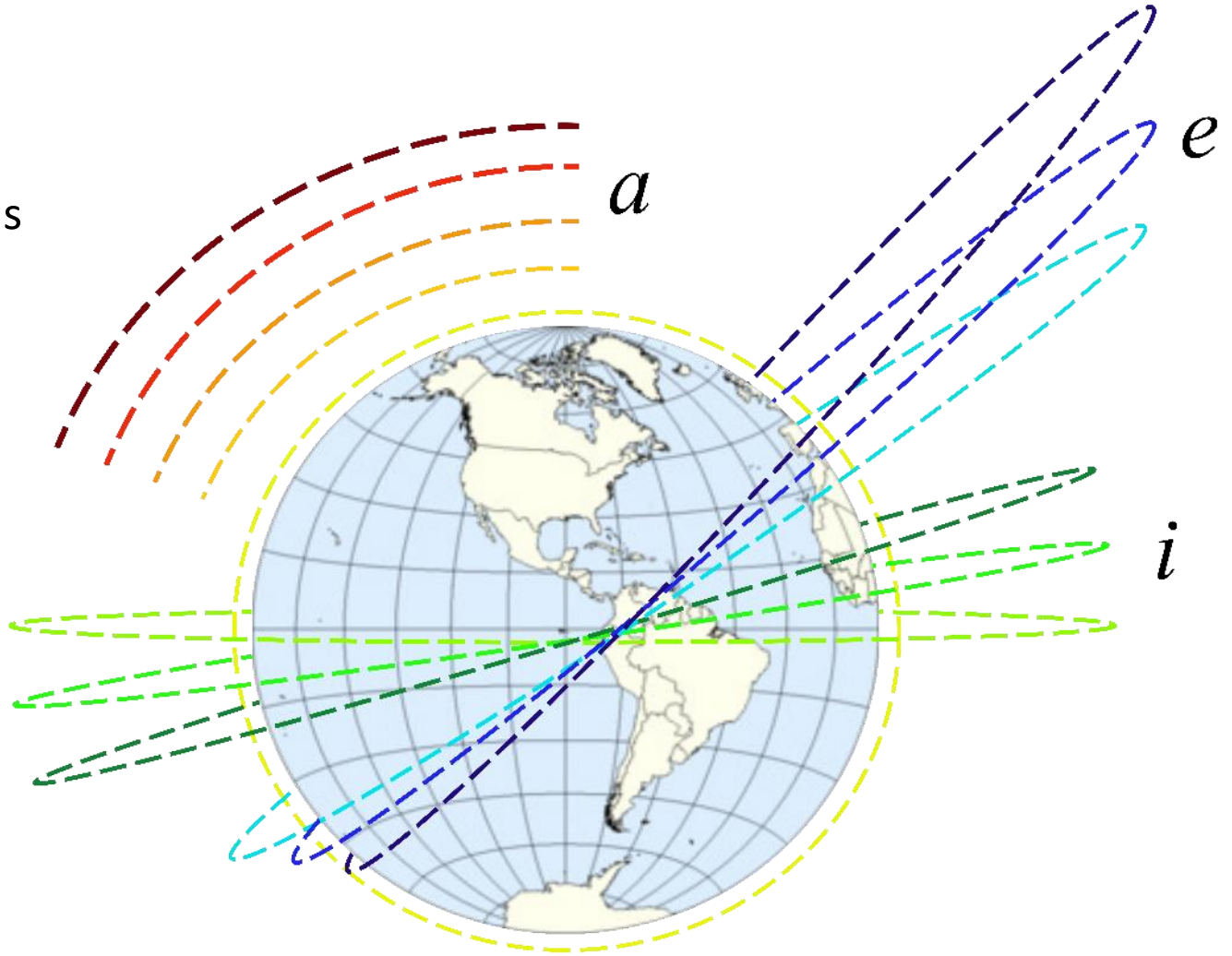
SIMULATIONS

We study the impact of adding satellite observations with different orbital parameters, in particular:

- **Semi-major axis – *a***
- **Inclination angle – *i***
- **Eccentricity – *e***

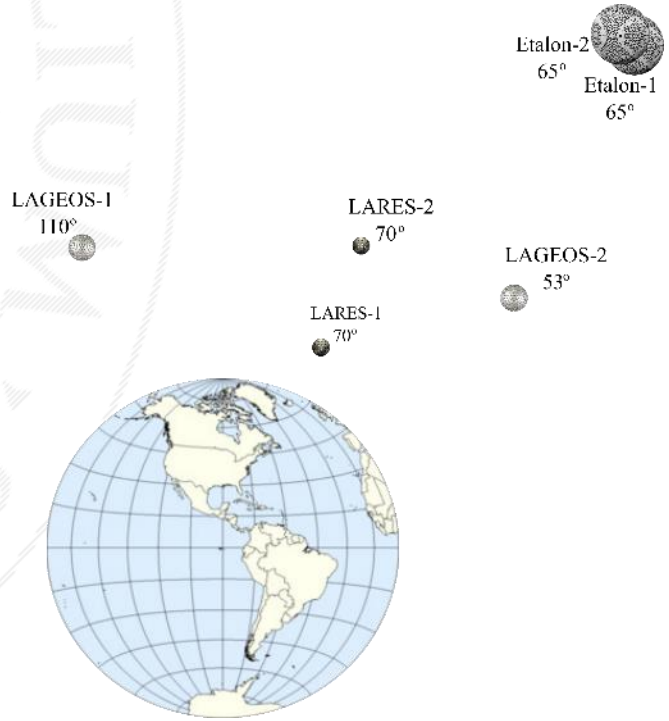
on the determination of geodetic parameters:

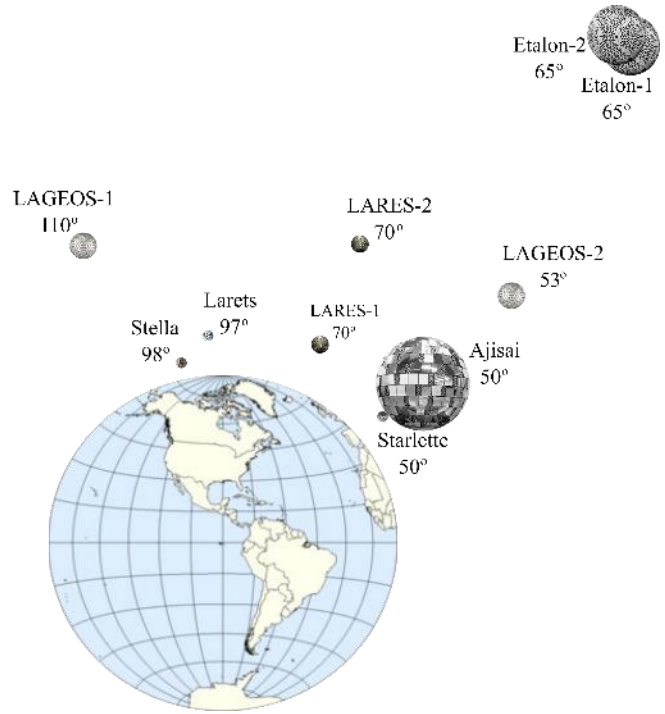
- Earth rotation parameters,
- Geocenter,
- The low-degree spherical harmonics of the Earth's gravity field up to d/o 6/6.



SIMULATIONS - SOLUTIONS

SOLUTION	REFERENCE FRAMES	GRAVITY POTENTIAL
Satellites	LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2 + a simulated satellite	LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2, Starlette, Stella, Ajisai, Larets + a simulated satellite
Determinated parameters	Station coordinates **ERP** **Geocenter** Gravity potential	Station coordinates ERP **Geocenter** **Gravity potential**





SIMULATIONS – DATA PROCESSING

SOLUTION	REFERENCE FRAMES				GRAVITY POTENTIAL			
Satellites	LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2 + a simulated satellite				LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2, Starlette, Stella, Ajisai, Larets + a simulated satellite			
Determinated parameters	Station coordinates **ERP** **Geocenter** Gravity potential				Station coordinates ERP **Geocenter** **Gravity potential**			
	LAGEOS-1/-2	**Etalon-1/-2**	**LARES-1**	**LARES-2**	**Starlette**	**Stella**	**Ajisai**	**Larets**
Reference frames - solution	+	+	+	+				
Gravity potential - solution	+	+	+	+	+	+	+	+
Osculating elements	a, e, i, Ω, ω, u_0 (1 set per 7 days)							
Constant and once-per-revolution accelerations	S_0 , S_S , S_C		D_0 , S_0		S_0 , S_S , S_C			
	1 set per 7 days							
Observation noise level [mm]	6	15	9	6	15			
Number of collected observations per 7 days	1900	350	1000	1200	1400	500	1900	500
Weighting	1.00	0.25	0.44	1.00	0.25			

SIMULATIONS – DATA PROCESSING

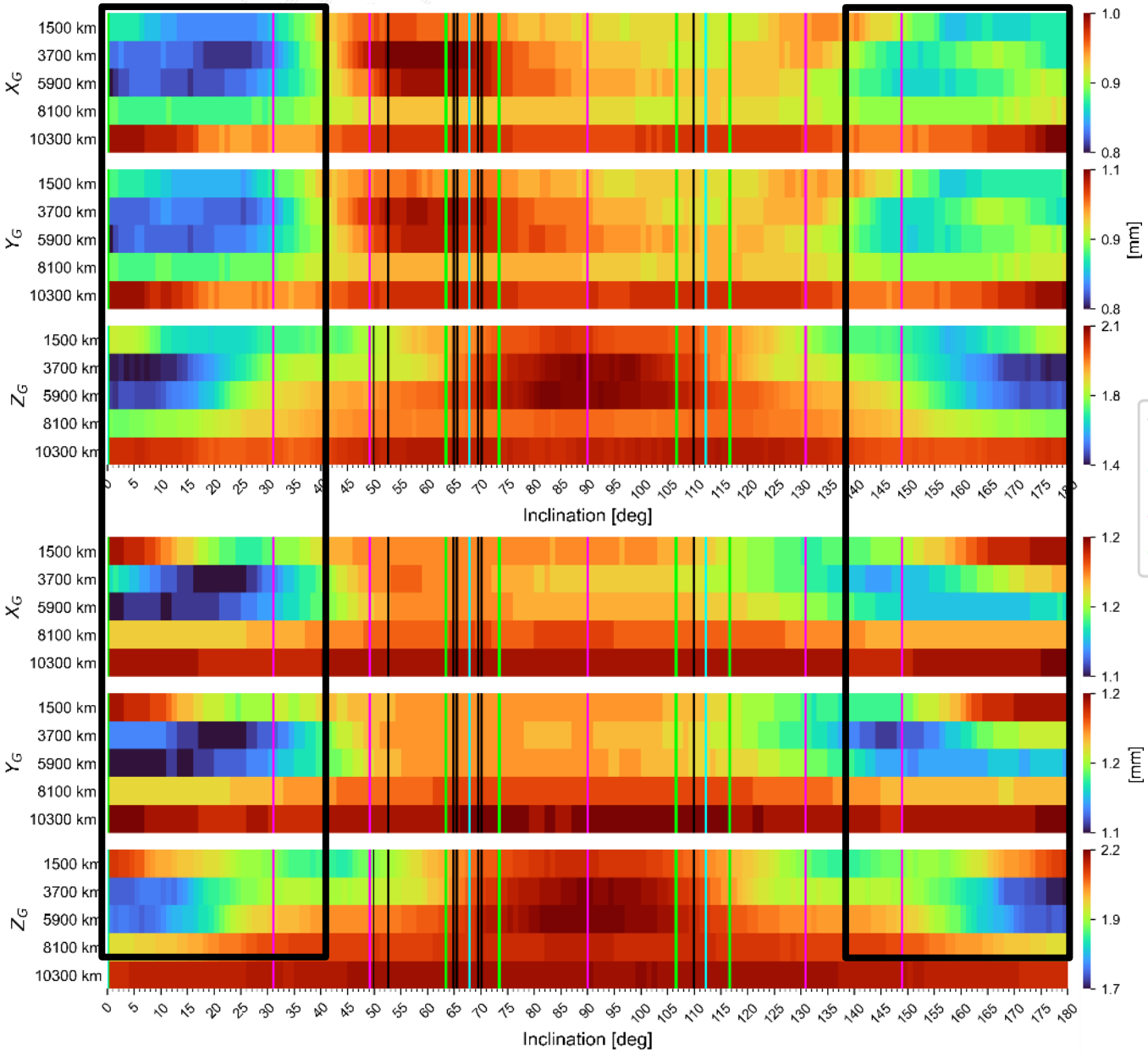
SOLUTION	REFERENCE FRAMES	GRAVITY POTENTIAL
Satellites	LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2 + a simulated satellite	LAGEOS-1/-2, Etalon-1/-2, LARES-1/-2, Starlette, Stella, Ajisai, Larets + a simulated satellite
Determinated parameters	Station coordinates **ERP** **Geocenter** Gravity potential	Station coordinates ERP **Geocenter** **Gravity potential**

	LAGEOS-1/-2	Etalon-1/-2	LARES-1	LARES-2	Starlette	Stella	Ajisai	Larets
Reference frames - solution	+	+	+	+				
Gravity potential - solution	+	+	+	+	+	+	+	+

	LOW – 7,800	MEDIUM – 10,000	HIGH – 12,200	HIGHER – 14,400	HIGHEST – 16,600
Osculating elements	a, e, i, Ω, ω, u_0 (1 set per 7 days)				
Constant and once-per-revolution accelerations	D_0 , S_0				
	1 set per 7 days				
Observation noise level [mm]	9	6	6	9	15
Number of collected observations per 7 days	1000	1000	900	550	350
Weighting	0.44	1.00	1.00	0.44	0.25

RESULTS – GEOCENTER COORDINATES

The formal errors of geocenter coordinates – **depending on the semi-major axis**



REFERENCE FRAMES - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + a simulated satellite

Lower formal errors are obtained in solutions for reference frames - even though the number of satellites in the solution is smaller.

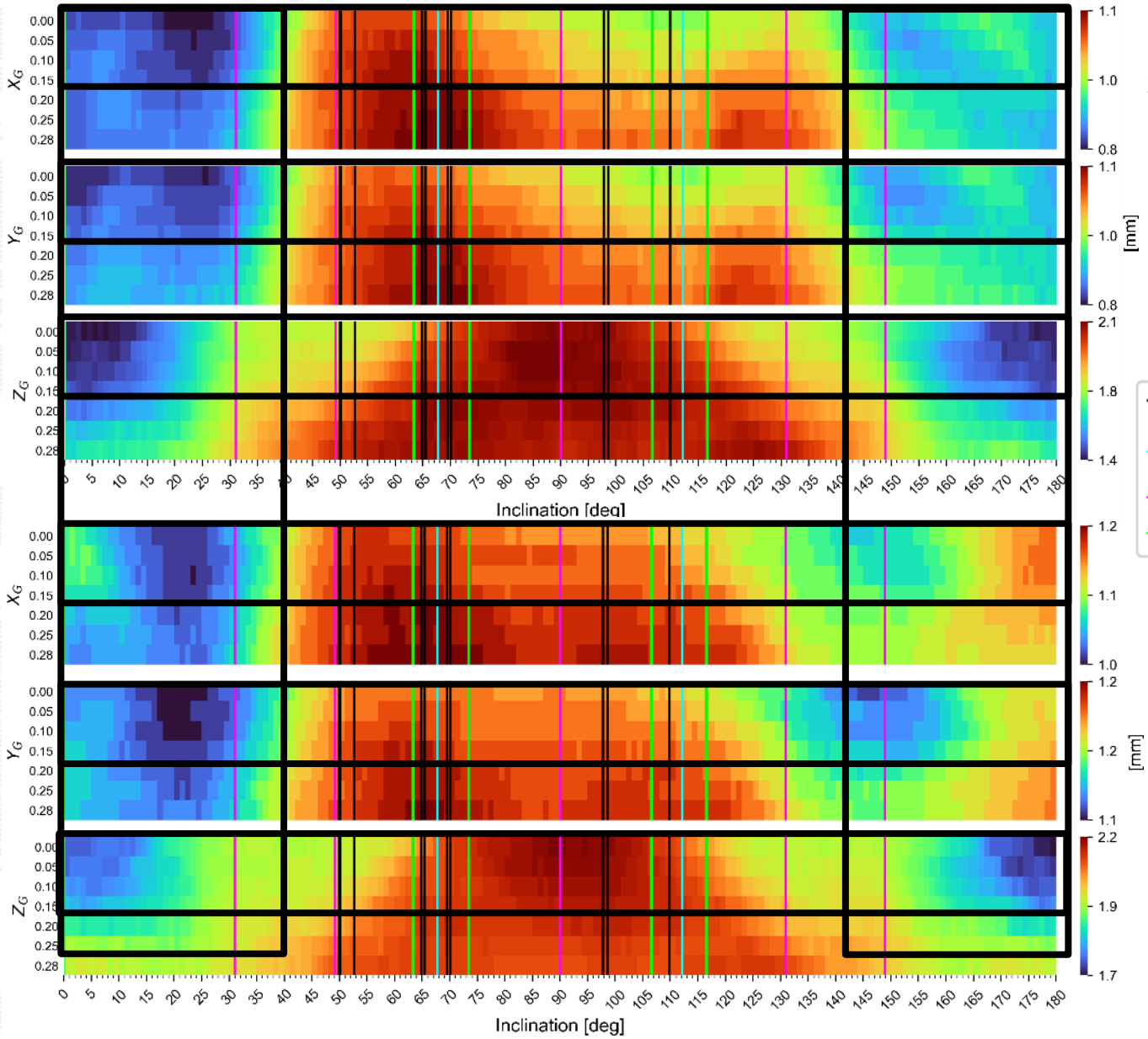
The optimal inclination angles for the geocenter are from 0-40°, and from 140-180°. In addition, the lowest formal errors are for satellite altitudes around 3700 and 5900 km.

GRAVITY POTENTIAL - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + Starlette + Stella + Ajisai + Larets + a simulated satellite

RESULTS – GEOCENTER COORDINATES

The formal errors of geocenter coordinates – **depending on the eccentricity**



i satellites
critical *i* - gravity potential
critical *i* - ΔΩ
critical *i* - Δω

REFERENCE FRAMES - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + a simulated satellite

Lower formal errors are obtained from solutions for reference systems - even though the number of satellites in the solution is smaller.

The optimal inclination angles for the geocenter are from 0-40°, and from 140-180°.

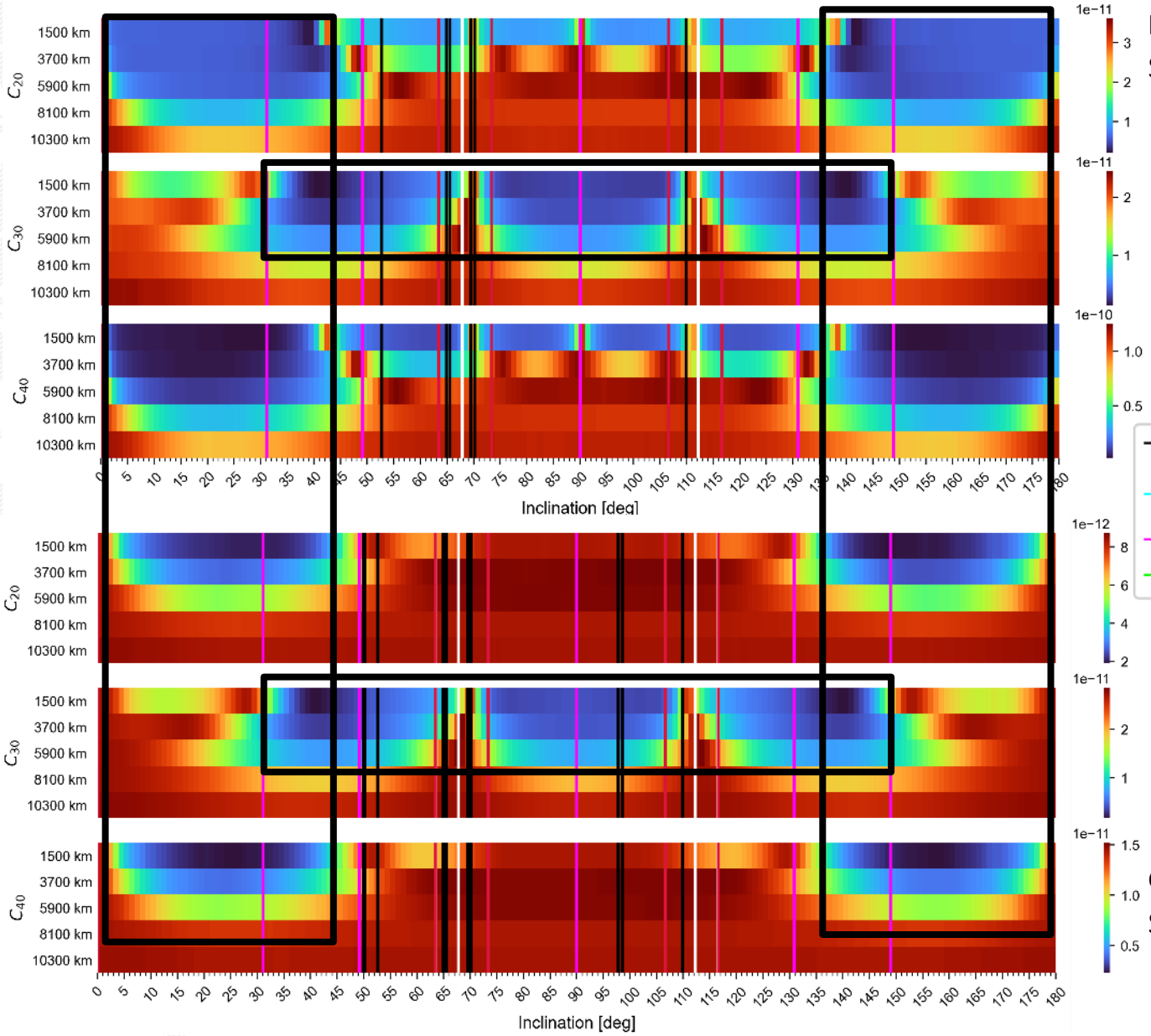
The smallest formal errors are achieved by solutions with a satellite in a circular or near-circular orbit (eccentricity up to 0.15).

GRAVITY POTENTIAL - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + Starlette + Stella + Ajisai + Larets + a simulated satellite

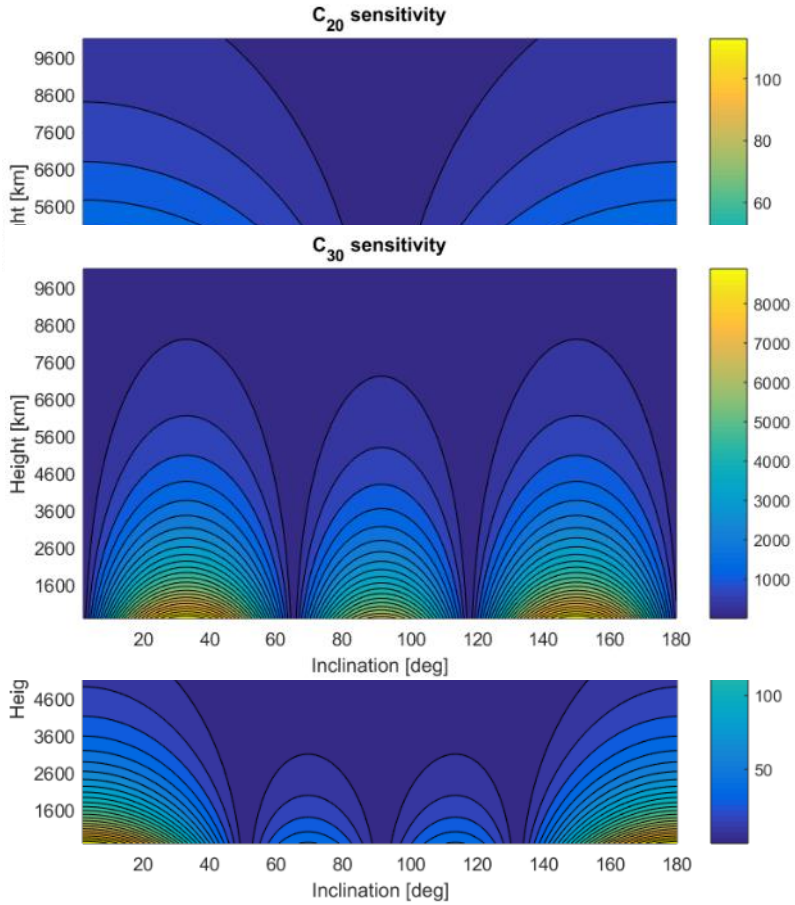
RESULTS – ZONAL HARMONICS

The formal errors of coefficients – C_{20}, C_{30}, C_{40} – **depending on the semi-major axis**



REFERENCE FRAMES - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + a simulated satellite

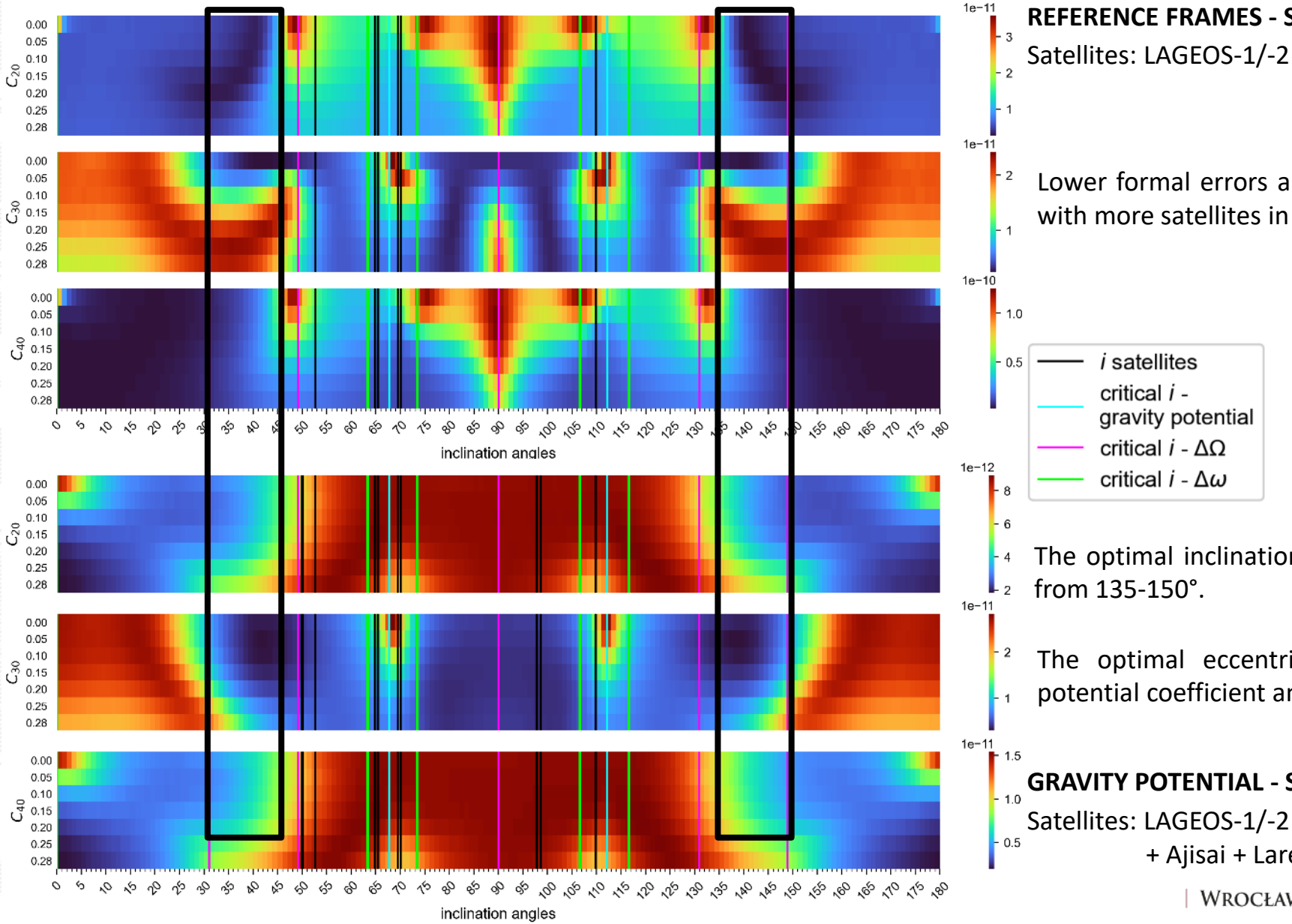


GRAVITY POTENTIAL - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + Starlette + Stella + Ajisai + Larets + a simulated satellite

RESULTS – ZONAL HARMONICS

The formal errors of coefficients – C_{20}, C_{30}, C_{40} – **depending on the eccentricity**



REFERENCE FRAMES - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + a simulated satellite

Lower formal errors are obtained from solutions for gravity potential- with more satellites in the solution.

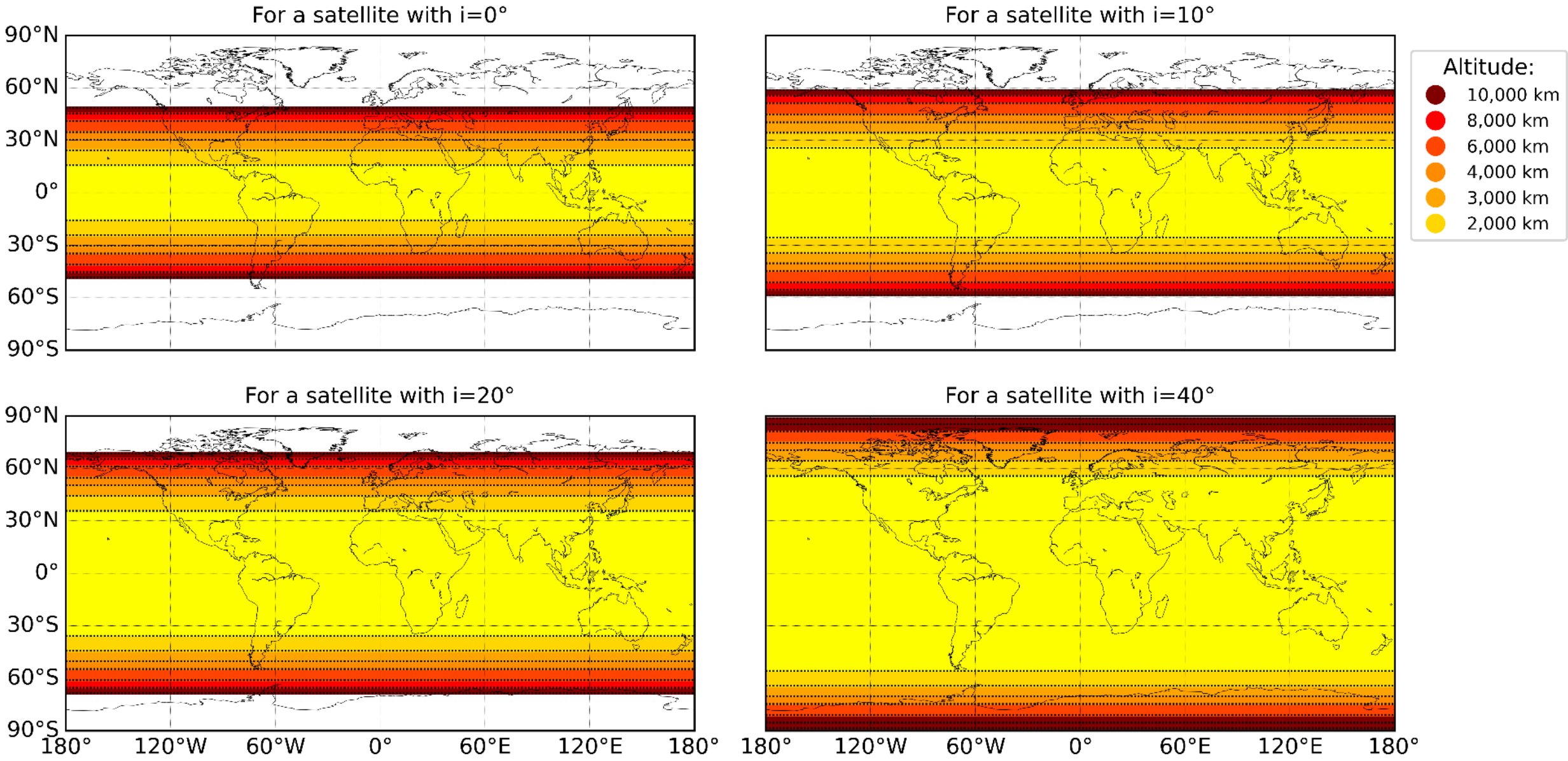
The optimal inclination angles for the geocenter are from 30-45°, and from 135-150°.

The optimal eccentricities of the orbit depend on the harmonic potential coefficient and also on the inclination angles.

GRAVITY POTENTIAL - SOLUTION

Satellites: LAGEOS-1/-2 + Etalon-1/-2 + LARES-1/-2 + Starlette + Stella + Ajisai + Larets + a simulated satellite

VISIBILITY OF SATELLITE



SUMMARY

- **For geocenter coordinates:**
  - the lower formal errors are obtained in solutions for reference frames,
  - the optimum values of inclination are in the range of 0-40° and 140-180°,
  - the optimum values of the semi-major axis are 10,000 or 12,200 km,
  - the optimum values of eccentricity are in the range of 0.00-0.15.
- **For zonal harmonics:**
  - the lower formal errors are obtained in solutions for gravity potential,
  - the optimum values of inclination are in the range of 30-45° and 135-150°,
  - the optimum values of the semi-major axis are 7,800 or 10,000 km.

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THANK YOU FOR YOUR ATTANTION

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